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(54) Bearing assembly for turbines

(57) The invention recites a power turbine assembly including a turbine rotor and a plurality of turbine blades mounted to said rotor and adapted to rotate said rotor in response to a flow of hot gas over said blades. A support structure having a journal bearing and at least one other bearing supports said rotor for rotation, said journal bearing having a proximal end and a distal end with respect to said turbine blades. A supply of lubricant communicates with said journal bearing to provide lubricant between said rotor and an inner surface of said journal bearing, said lubricant damping rotational frequencies of said rotor and creating a temperature gradient from greater than about 1000°F at said blades to less than about 350°F at said distal end.

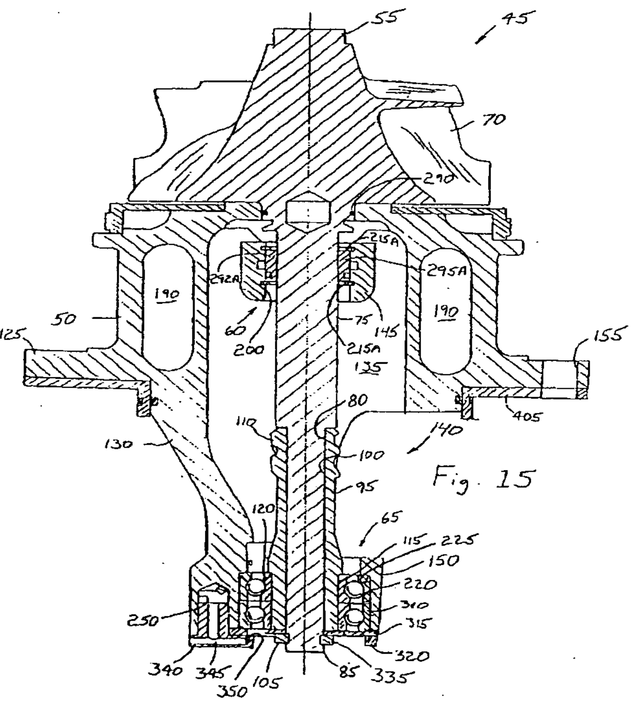

Fig. 15

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[0010] In yet another construction, the invention provides a method of supporting and aligning a high-speed turbine rotor having a drive gear with a lower speed rotor having a driven gear such that the high-speed turbine rotor is able to drive the lower speed rotor. The method includes the acts of providing a speed reducing cartridge and supporting the high-speed turbine rotor within a housing for rotation about a first axis, the housing including a journal bearing and a non-journal bearing supporting the turbine rotor for rotation. The method also includes the acts of supporting the lower speed rotor within the speed reducing cartridge such that the lower speed rotor is rotatable about a second axis and interconnecting the housing and the speed reducing cartridge with an adjusting member such that the first axis is offset a distance from the second axis. In addition, the method includes the acts of engaging the drive gear and the driven gear such that a backlash between the gears is present and adjusting the adjusting member to change the distance between the first axis and the second axis to achieve a desired backlash.

[0011] .Additional features and advantages will become apparent to those skilled in the art upon consideration of the following detailed description of preferred embodiments exemplifying the best mode of carrying out the invention as presently perceived.

Brief Description of the Drawings

[0012] The detailed description particularly refers to the accompanying figures in which:

Fig. 1 is a schematic representation of a combustion turbine engine having a separate gasifier turbine and power turbine;
Fig. 2 is a perspective view of a power turbine cartridge embodying the invention;
Fig. 3 is a front view of the turbine rotor assembly of the power turbine cartridge of Fig. 2;
Fig. 4 is a partially exploded perspective view of the power turbine cartridge of Fig. 2;
Fig. 5 is a partially exploded perspective view of the power turbine cartridge of Fig. 2;
Fig. 6 is a front view of the housing of the power turbine cartridge of Fig. 2;
Fig. 7 is a cross-sectional view of the housing of Fig. 6, taken along line 7-7 of Fig. 6;
Fig. 8 is an enlarged sectional view of a portion of the housing of Fig. 6, taken along line 8-8 of Fig. 7;
Fig. 9 is a cross-sectional view of the housing of Fig. 6, taken along line 9-9 of Fig. 7;
Fig. 10 is a cross-sectional view of the housing of Fig. 6, taken along the plane defined by the oil passages;
Fig. 11 is a cross-sectional view of the housing of Fig. 6, taken along line 11-11 of Fig. 7;
Fig. 12 is an enlarged view of the second bearing support of Fig. 11;
Fig. 13 is an enlarged sectional view of the first bearing of the housing of Fig. 6;
Fig. 14 is an enlarged sectional view of the second bearing of the housing of Fig. 6;
Fig. 15 is a cross-sectional view of the power turbine cartridge of Fig. 2;
Fig. 16 is a partial cross-sectional view of a speed-reducing cartridge embodying the invention;
Fig. 17 is a sectional view of the eccentric ring of Fig. 16.

Detailed Description of the Drawings

[0013] As shown schematically in Fig. 1, a turbine or microturbine engine 10 includes a compressor 15, a combustor 20, a gasifier turbine 25, a power turbine 30, a generator 35, and a recuperator or heat exchanger 40. The gasifier turbine 25, power turbine 30, generator 35, and compressor 15 each include rotary elements. The rotary elements are either directly or indirectly coupled to one another so that rotation of the gasifier turbine rotary element produces a corresponding rotation of the compressor rotary element and rotation of the power turbine rotary element produces a corresponding rotation of the generator rotary element. Alternatively, a single turbine can be used in place of the gasifier turbine 25 and power turbine 30.

[0014] While a generator 35 has been illustrated and described as being driven by the gasifier turbine 25, a person having ordinary skill in the art will realize that the engine 10 is capable of driving virtually any piece of rotating equipment. For example, turbine engines of the type described herein are commonly used to drive pumps, compressors, generators, conveyors, etc. or any combination thereof. Therefore, the present invention should not be limited to systems that operate to drive generators alone.

[0015] Rotation of the compressor rotary element draws atmospheric air into the compressor 15 so that the compressor 15 may pressurize the air. The compressor 15 discharges the pressurized (compressed) air to the cool flow path of the recuperator 40 for preheating.

[0016] The preheated compressed air exits the recuperator 40 and enters the combustor 20 where it mixes with a fuel (e.g., propane, kerosene, natural gas, gasoline, diesel, etc.). Alternatively, the fuel may be mixed with the air at the compressor 15 intake. The fuel-air mixture is ignited and combusted within the combustor 20 to produce a hot flow of products of combustion. The products of combustion flow through the gasifer turbine 25, transfer thermal and kinetic energy to the gasifier turbine 25, and induce rotation of the rotary elements of the gasifier turbine 25 and compressor 15. The gasifier turbine 25 thus supplies the rotary energy needed to drive the compressor 15.

[0017] The gas exits the gasifier turbine 25 and enters the power turbine 30. Again, the gas transfers thermal and kinetic energy to the power turbine 30, thereby in-

50 adjacent the hot bladed portion 70 of the turbine rotor 55. As shown in Fig. 9 the water jacket 190 is sized and positioned such that the wall thickness of the housing 50 remains substantially constant throughout, thereby reducing the potential thermal stress. Plugs 195 inserted into the water inlets 180 and water outlet 185, as illustrated in Figs. 4 and 5, close and seal the water jacket 190 for constructions that do not use the water jacket 190.

[0030] While the water jacket 190 has been described as using water, many other fluids can be used as a coolant. For example, compressed air from the compressor 15 could pass through the water jacket 190 to provide cooling and to receive additional preheat.

[0031] The first bearing support 145 extends into the center of the housing 50 in a cantilever fashion and provides a location for the first bearing 75. As shown in Fig. 9, the first bearing support 145 includes a cylindrical bore 200 sized to receive the first bearing 60 and a shoulder 205 that positions the bearing 60 axially. A snap-ring groove 210 is also provided to allow a snap-ring 215 to lock the bearing 60 at the desired axial location.

[0032] The second bearing support 150 includes a cylindrical bore 220 and a shoulder 225 that positions the top of the second bearing 65 in the desired location. A circumferential groove 230 is positioned approximately near the center of the cylindrical bore 220. The groove's function will be described below.

[0033] The bearing supports 145, 150 and drive gear 110 require a flow of lubricant in order for the power turbine cartridge 45 to operate properly. As shown in Fig. 7, the first lubricant inlet 170 is in fluid communication with the first bearing support 145. Lubricant, typically oil, enters through the inlet 170 and flows through a passage 235 (shown in Fig. 8) that is cast, drilled, or otherwise formed within the housing 50. The passage 235 guides the lubricant to the first bearing support 145. The lubricant enters the bearing support 145 through an opening 240 best illustrated in Fig. 9. As the oil is used by the first bearing 60, it drains into the cavity 135 within the housing 50 and eventually out of the power turbine cartridge 45.

[0034] The second lubricant inlet 175, also shown in Fig. 7, provides fluid to the drive gear 110 and to the second bearing 65 disposed in the second bearing support 150. Again, a passage or a plurality of passages 245 are cast, drilled, or otherwise formed in the housing 50 to guide the fluid from the inlet 175 to the gear 110 and the bearing 65. Fig. 10 is a sectional view of the housing taken through the plane defined by the passages 245 and illustrates how the lubricant passes from the second oil inlet 175 to the second bearing support 150. The oil flows within a downwardly extending passage 245A to a lower oil reservoir 250 where it is directed to one of a plurality of locations. The lower oil reservoir 250 directs lubricating oil to drive gear jets 255 (shown in Figs. 9 and 11), upper second bearing jets 260 (shown in Fig. 12), and to lower second bearing jets 265 (shown in Figs. 14 and 15).

[0035] A gear passage 245B extends up to the gear jet 255 or plurality of gear jets where oil is admitted into the cavity 135. The gear jets 255 (visible in Figs. 4 and 5) are aligned to spray oil directly onto the drive gear 110 during operation. Another construction includes a second gear jet or plurality of gear jets fed from the downwardly extending passage 245A before the oil reaches the lower oil reservoir 250.

[0036] Jets as used herein can be as simple as a small hole sized to act like a nozzle to spray oil to the desired location. Other constructions use preformed nozzles that attach (e.g., thread) to the housing 50 and function as jets.

[0037] Oil within the lower reservoir 250 also flows to the upper second bearing jets 260 along the passage 245B. These jets 260 (shown in Figs. 9, 11-12, and 15), or in some constructions a single jet, are aligned to spray oil onto the top portion of the second bearing 65. Again, as with the drive gear oil supply, oil can be routed from the downwardly extending passage 245A to the upper second bearing jet 260 before it enters the lower reservoir 250.

[0038] To facilitate drainage from the second bearing 65, oil is removed via the groove 230 disposed in the cylindrical bore 220 of the second bearing support 150. The oil exits through passages 275 (shown in Fig, 12) and drains out of the power turbine cartridge 45.

[0039] The remaining oil is supplied to the lower portion of the second bearing 65 in a manner that will be described below. Thus, the second bearing 65 is fully lubricated using only a single oil inlet 175 into the housing. After the oil is used, it drains out the bottom of the power turbine cartridge 45 or flows out the window portion 140 of the housing 50.

[0040] Fig. 4 illustrates the assembly of the turbine rotor 55 into the housing 50. A backplate 280 and insulating plate 285 provide some thermal separation between the bladed portion 70 of the turbine rotor 55 and the housing 50. A piston ring 290 provides a seal between the turbine rotor 55 and the housing 50 to reduce or prevent hot gas flow from passing into the housing. Thus, the hot gas is substantially isolated from the housing 50. The first bearing assembly 60 slides onto the first bearing portion 75 of the turbine rotor 55 and is supported within the housing 50 at the first bearing support 145. The snap-ring 215 locks the first bearing 60 in the proper axial position.

[0041] Fig. 13 better illustrates the first bearing 60 installed in the housing 50. The first bearing 60 includes a tilting pad journal bearing 292. While a tilting pad journal bearing is preferred, other journal bearings also can be used with the invention. For example, a two-piece offset half journal bearing could be used in place of the tilting pad journal bearing,

[0042] Titling pad bearings provide damping for the turbine rotor 55, along with an additional tolerance for

power turbine sump 380, a generator flange mount 385, a generator sump 390, and an oil sump 395. The oil sump 395 is a cavity disposed at the lowest level of the speed-reducing cartridge 160. Paths provided in the speed-reducing cartridge 160 direct lubricating oil to the sump 395 where it is gathered and recycled. In other constructions, the oil drains directly into an oil tank rather than into a sump as illustrated in Fig. 16.

[0055] The generator flange mount 385 provides a surface to which the generator 35 can be attached. The speed-reducing cartridge 160 of Fig. 16 provides bearing supports for the generator 35. A shaft extends out of the generator cartridge and supports the driven gear 165. In other constructions, the generator is a self-contained cartridge much like the power turbine cartridge 45 and requires no additional supports beyond the generator flange mount 385.

[0056] The position of the generator flange mount 385 is precisely located a distance from the power turbine flange mount 375. The distance is approximately equal to the sum of the radii of the drive gear 110 and the driven gear 165. The size of the drive gear 110 is fixed for the power turbine cartridge 45. The size of the driven gear 165 is calculated in a known way to assure rotation of the generator 35 at the proper speed. For example, a 2" diameter drive gear 110 on a power turbine cartridge 45 that rotates at 25,000 RPM would have to engage a 13.9" diameter driven gear 165 to drive a generator 35 at 3600 RPM.

[0057] The power turbine flange mount 375 is similar to the generator flange mount 385. The power turbine flange mount 375 provides a flat surface to which the power turbine cartridge 45 may attach. In addition, the power turbine flange mount includes a central bore sized to engage the power turbine cartridge 45. The central bore 400 assures that the power turbine cartridge 45 is properly positioned and aligned.

[0058] The power turbine cartridge 45 extends into the turbine sump 380. The sump 380 is a cavity that collects the lubricating oil that drains from the power turbine cartridge 45 and directs it toward the oil sump 395. Likewise, the driven gear 165 extends into the generator sump 390 which collects any lubricating oil that may drip from the driven gear 165 and directs it toward the oil sump 395.

[0059] Due to the high-speed rotation of the turbine rotor 55 and the need for dynamic stability, it is necessary to precisely control the backlash between the drive gear 110 and the driven gear 165. To do this, the power turbine cartridge 45 is fitted with an eccentric ring 405 (illustrated in Figs. 15-17) that is sized to engage the speed-reducing cartridge central bore 400. Rotation of the ring 405 about the power turbine cartridge 45 shifts the axis of rotation toward or away from the axis of rotation of the generator 35. The ring 405 has a circular inside diameter sized to tightly engage the power turbine cartridge 45, best illustrated in Fig. 15 and a circular outside diameter sized to engage the central bore 400 of the speed-reducing cartridge 160 as shown in Fig. 16. However, as is shown in Fig. 17 the inside and outside diameters are not concentric. Instead, the diameters are shifted relative to one another to produce the eccentric ring 405. The ring 405 enables the precise setting of the desired backlash. It should be noted that Figs. 15 and 17 greatly exaggerate the eccentricity of the ring for illustrative purposes. In reality the eccentricity allows for adjustments up to about 0.030 inches, with larger adjustments possible with other rings.

[0060] While oil has been described herein as the lubricating fluid, a person having ordinary skill in the art will realize that other fluids can be used as lubricants. Therefore, the invention should not be limited to the use of oil alone.

[0061] Although the invention has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of the invention as described and defined in the following claims.

Claims

1. A power turbine assembly comprising:

   a turbine rotor;
   a plurality of turbine blades mounted to said rotor and adapted to rotate said rotor in response to a flow of hot gas over said blades;
   a support structure having a journal bearing and at least one other bearing supporting said rotor for rotation, said journal bearing having a proximal end and a distal end with respect to said turbine blades; and
   a supply of lubricant communicating with said journal bearing to provide lubricant between said rotor and an inner surface of said journal bearing, said lubricant damping rotational frequencies of said rotor and creating a temperature gradient from greater than about 1000°F at said blades to less than about 350°F at said distal end.

2. The power turbine assembly of claim 1, wherein the first bearing is a tilting-pad journal bearing and wherein the at least one other bearing comprises only non-journal-type bearings.

3. The power turbine assembly of claim 1, wherein the at least one other bearing is a single duplex bearing, the journal bearing and duplex bearing providing the only support for the turbine rotor.

4. The power turbine assembly of claim 1, wherein the turbine rotor rotates at a speed above about 25,000 RPM.

24. The structure for supporting a combustion turbine of claim 23, wherein the second bearing is a non-journal type bearing.

25. The structure for supporting a combustion turbine of claim 23, wherein the journal bearing is a tilting-pad journal bearing and the second bearing is a duplex ball bearing.

26. The structure for supporting a combustion turbine of claim 23, further comprising a retainer supporting the second bearing against thrust load and further providing a lubricant flow path and a lubricant outlet jet adjacent the lower portion of the second bearing.

27. The structure for supporting a combustion turbine of claim 26, further comprising a spring member cooperating with the retainer to apply a predictable thrust preload to the second bearing.

28. The structure for supporting a combustion turbine of claim 23, wherein the housing is formed from an integrally cast single piece.

29. The structure for supporting a combustion turbine of claim 23, wherein the lubricant inlet further includes a first inlet supplying lubricant flow to the journal bearing and a second inlet providing lubricant flow to the drive gear and the second bearing.

30. The structure for supporting a combustion turbine of claim 23, wherein the second bearing is a duplex ball bearing.

31. The structure for supporting a combustion turbine of claim 23, wherein the drive gear is at least an AGMA class 12 gear.

32. The structure for supporting a combustion turbine of claim 23, wherein the housing defines a water jacket having an inlet and an outlet, and wherein a coolant flow enters the water jacket through the inlet, flows through the water jacket and out the outlet to provide cooling to the housing.

33. The structure for supporting a combustion turbine of claim 23, wherein the journal bearing separates the hot turbine components from cool lubricated components.

34. The structure for supporting a combustion turbine of claim 23, wherein the sleeve is press-fit onto the turbine rotor such that the rotor and sleeve together define a composite shaft having a stiffness greater than that of the rotor alone such that the composite shaft has a higher first bending mode frequency than the operating frequency of the rotor.

35. The structure for supporting a combustion turbine of claim 34, further comprising a nut threaded onto the rotor adjacent the sleeve, the nut being tightened to retain the sleeve.

36. The structure for supporting a combustion turbine of claim 23, wherein the housing includes a plurality of lubricant jets, each jet aimed at one of the journal bearing, the drive gear, and the second bearing, the jets receiving a flow of lubricant and discharging it toward the aforementioned components.

37. A speed reducing cartridge for interfacing between a high-speed rotating turbine rotor and a lower speed rotating element, the cartridge comprising:

a power turbine cartridge including a journal bearing and a second bearing axially aligned with the journal bearing, the bearings supporting the turbine rotor for rotation about a first axis, the power turbine cartridge supported by the speed reducing cartridge;
a drive gear connected to the turbine rotor;
a driven gear connected to the lower speed rotating element;
a driven component housing supporting the lower speed rotating element for rotation about a second axis, the driven component housing supported by the speed reducing cartridge such that the drive gear and driven gear engage one another with a backlash; and
an adjusting assembly interconnecting the power turbine cartridge and the speed reducing cartridge, the adjusting assembly movable to adjust the backlash between the drive gear and the driven gear.

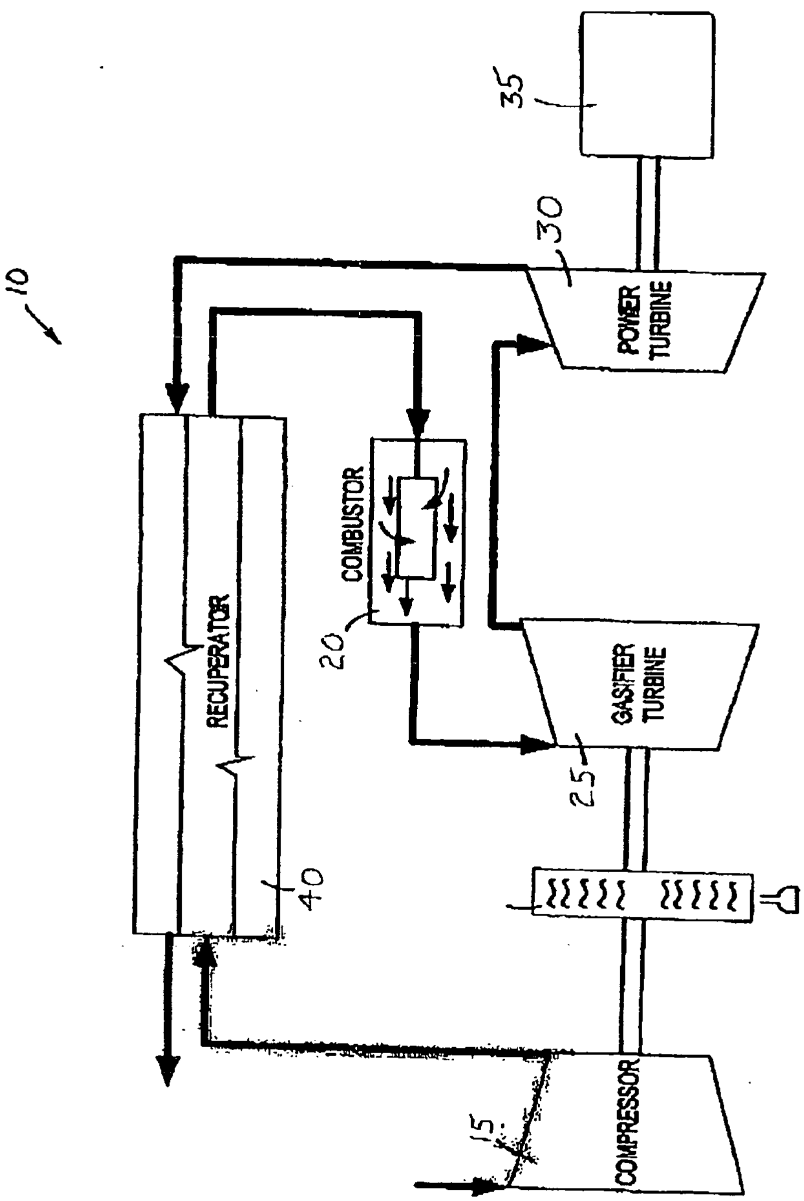
38. The speed reducing cartridge of claim 37, wherein the adjusting assembly includes an eccentric ring.

39. The speed reducing cartridge of claim 37, wherein the second bearing is a non-journal type bearing.

40. The speed reducing cartridge of claim 37, wherein the journal bearing is a tilting-pad journal bearing and the second bearing is a duplex ball bearing.

41. The speed reducing cartridge of claim 37, further comprising a retainer supporting the second bearing against thrust load and further providing a lubricant flow path and a lubricant outlet jet adjacent the lower portion of the second bearing.

42. The speed reducing cartridge of claim 41, further comprising a spring member cooperating with the retainer to apply a predictable thrust preload to the second bearing.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POWER TURBINE
COMBUSTOR
RECUPERATOR
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GASIFIER TURBINE
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COMPRESSOR

Fig. 1

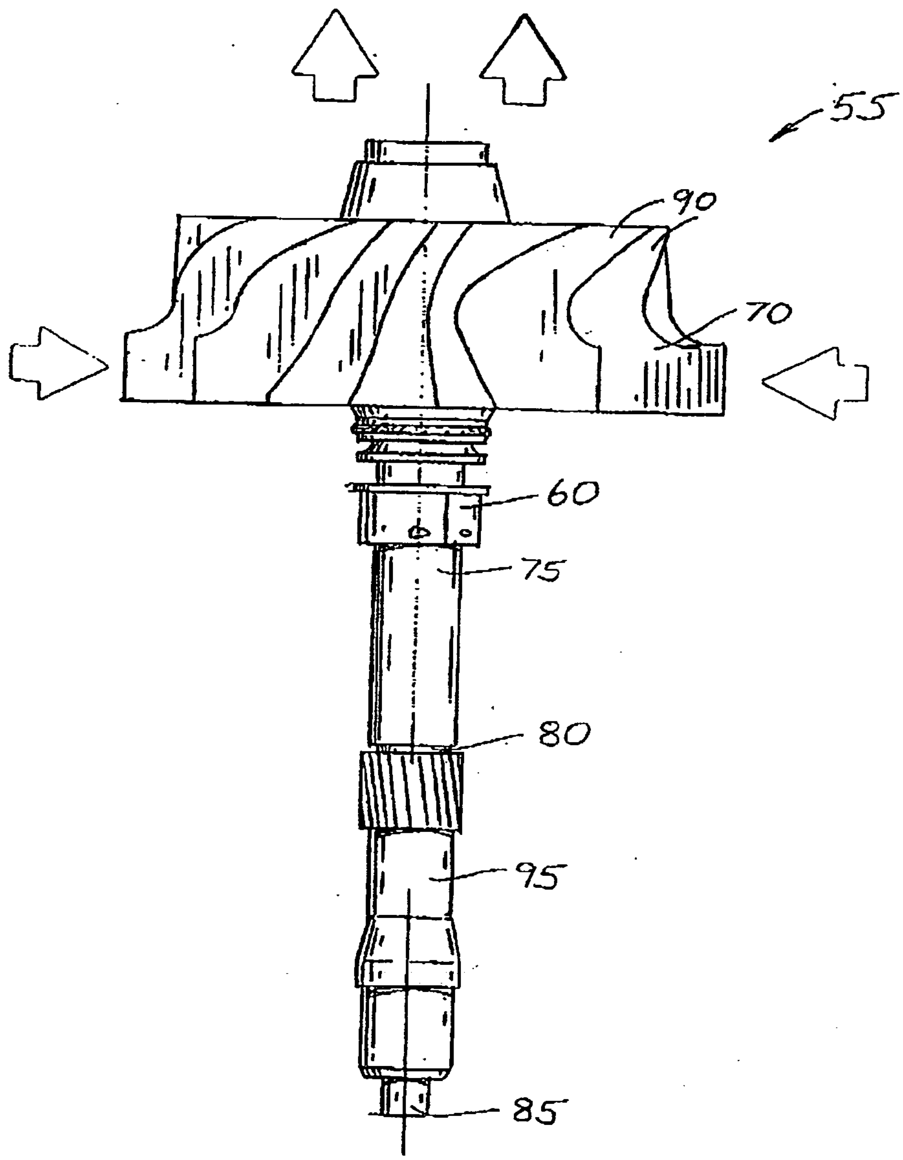

Fig. 3

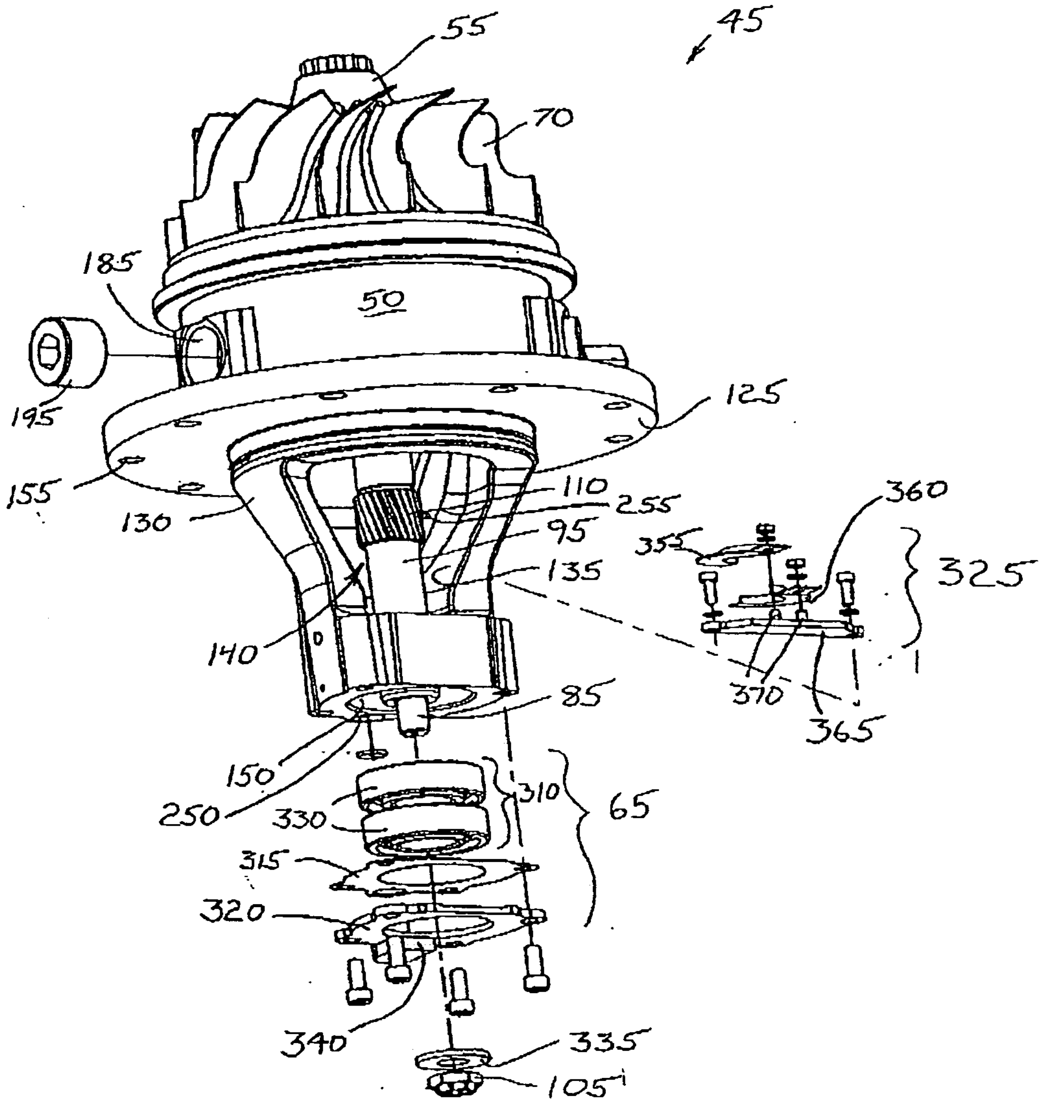
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Fig. 5

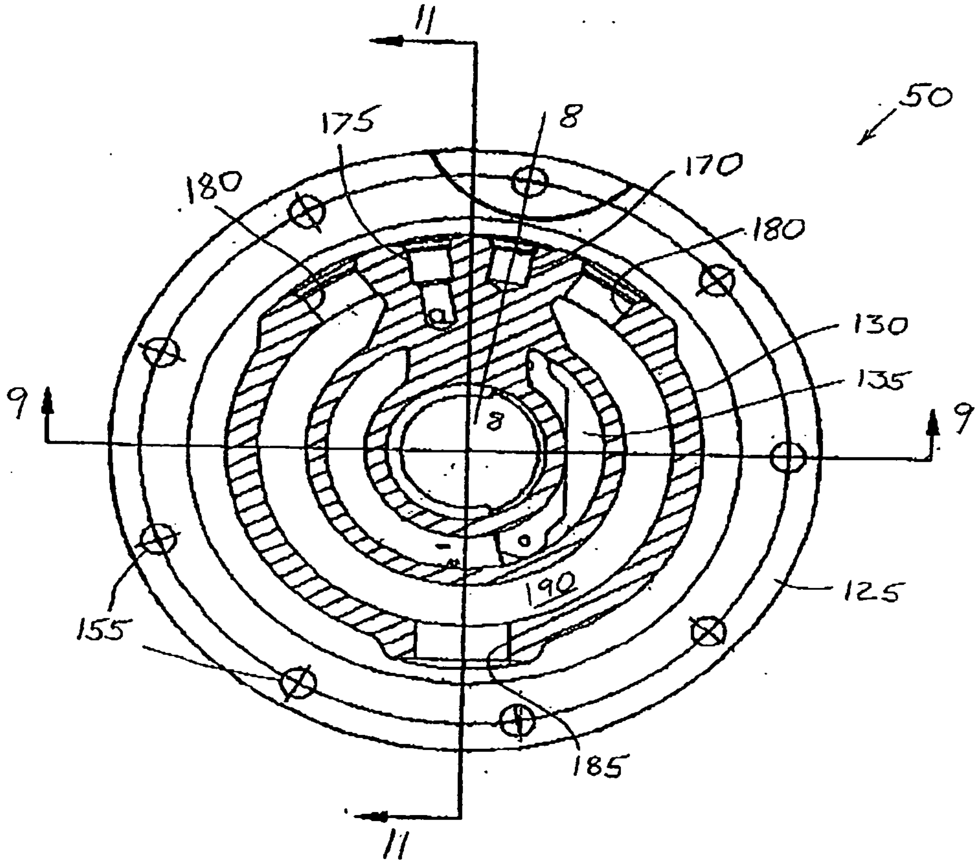

Fig. 7

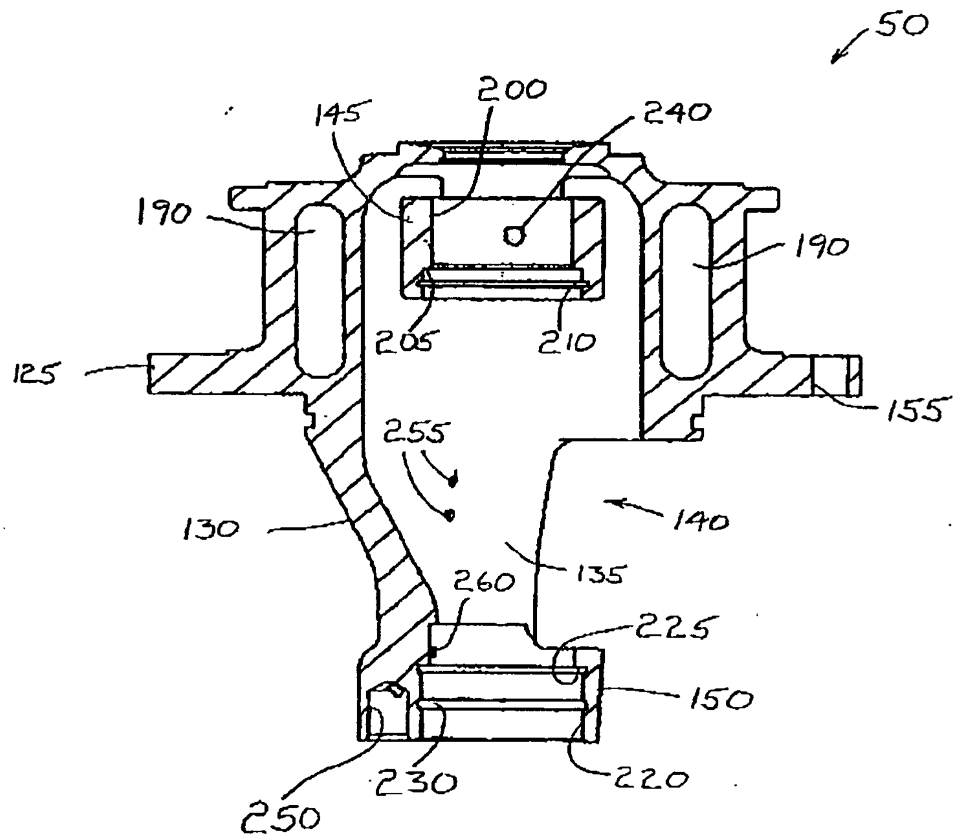
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Fig. 9

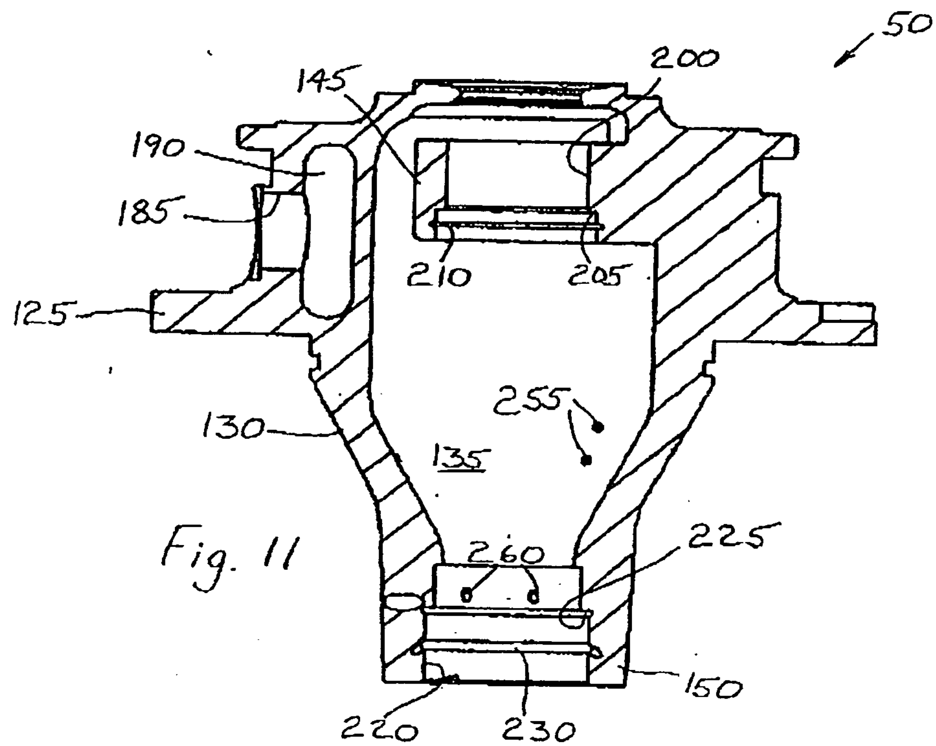
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Fig. 11

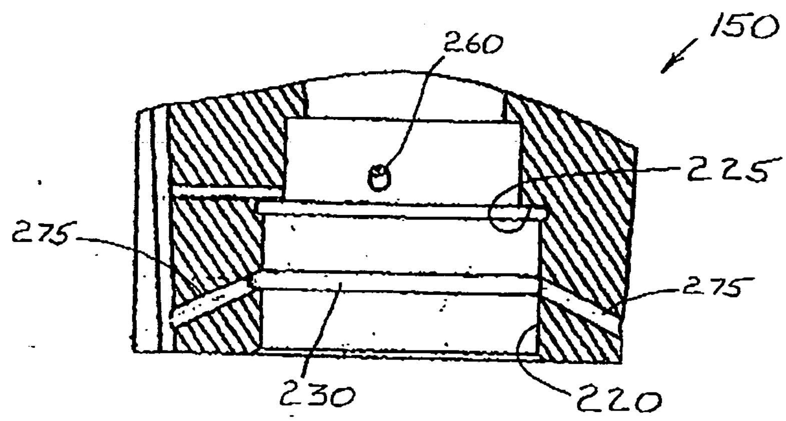
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Fig. 12

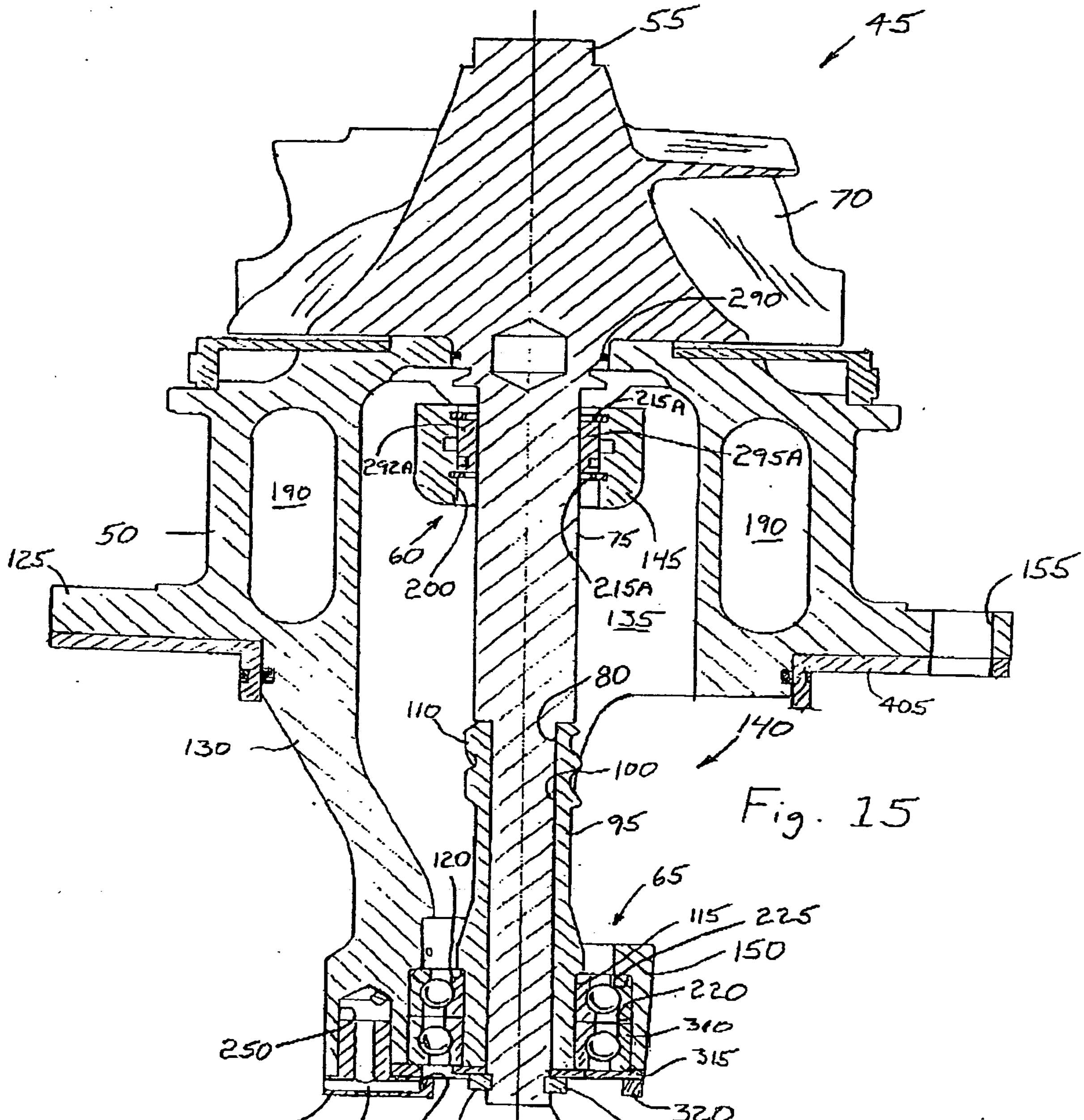
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Fig. 15

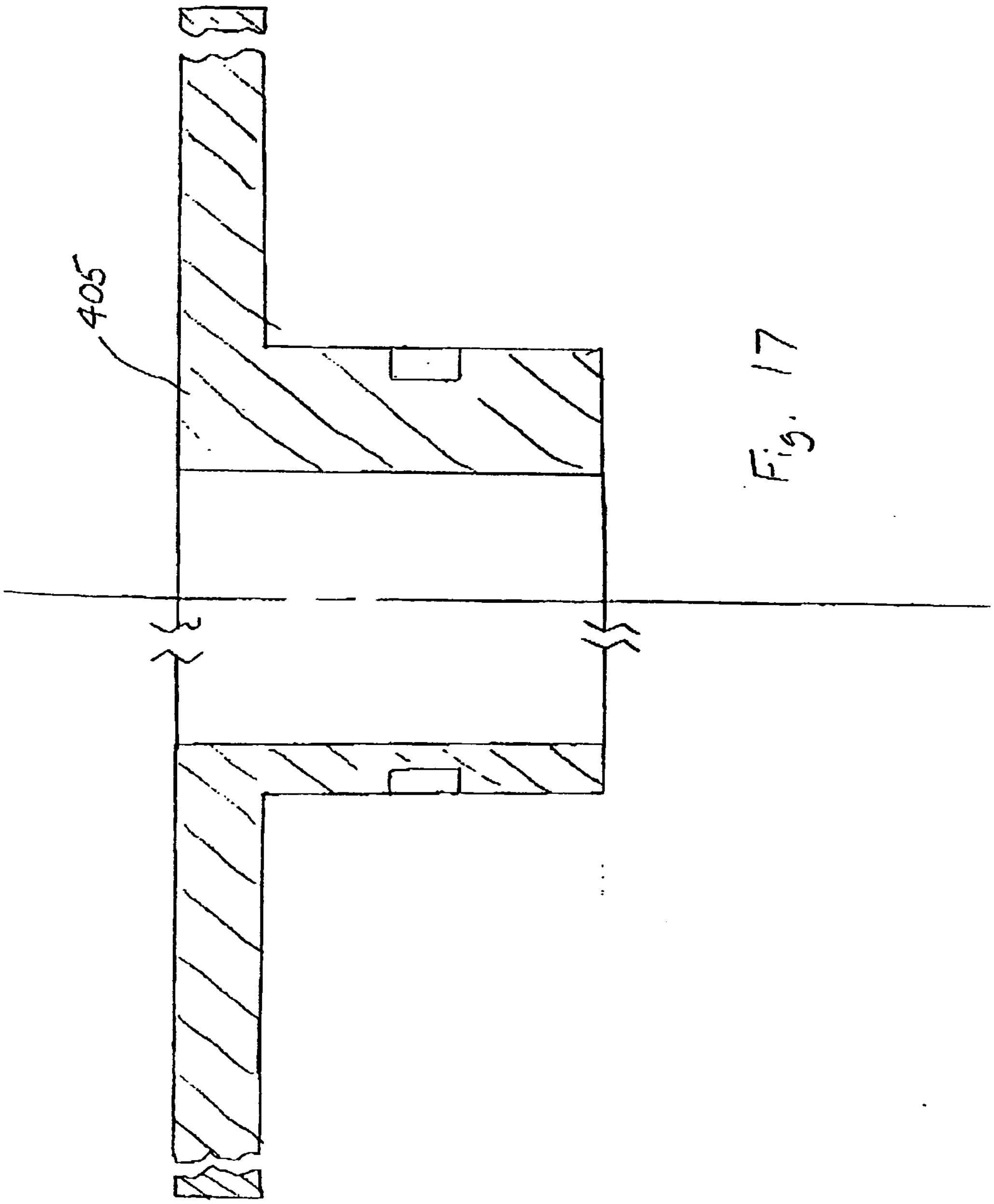

Fig. 17